ever, be evaluated by the methods for the evaluation of vanishing fractions. Y is clearly zero. X may be more readily obtained directly from the expression for U. From that expression we find that for a single circular current the attraction on such points is

$$X = 2\pi k \left\{ + \frac{a^2}{r^3} - \frac{3}{2}\frac{a^4}{r^5} + \frac{15}{8}\frac{a^6}{r^7} - \ldots . \right\}.$$

Hence, in the case of a bobbin, if x be the distance of the attracted point from O, the middle point of the axis of the bobbin, we have

$$\begin{aligned}\frac{X}{\mu} &= \int_{x+f}^{x-f}\int_{b}^{b+c} dr\,da\left(+ \frac{a^2}{r^3} - \frac{3}{2}\frac{a^4}{r^5} + \frac{15}{8}\frac{a^6}{r^7} - \ldots . \right) \\ &= -\frac{\overline{b+c}^3 - b^3}{6(x^2-f^2)^2}\left(\overline{x+f}^2 - \overline{x-f}^2\right) \\ &\quad + 3\frac{\overline{b+c}^5 - b^5}{40(x^2-f^2)^4}\left(\overline{x+f}^4 - \overline{x-f}^4\right) \\ &\quad - 5\frac{\overline{b+c}^7 - b^7}{112(x^2-f^2)^6}\left(\overline{x+f}^6 - \overline{x-f}^6\right) \\ &\quad + \ldots . . . ,\end{aligned}$$

which gives X for points situated on the axis for which x is not less than $(b+c+f)$.

December 12, 1872.

WILLIAM SPOTTISWOODE, M.A., Treasurer and Vice-President, in the Chair.

Announcement was made from the Chair that the President had appointed Dr. Sharpey a Vice-President.

The Presents received were laid on the Table, and thanks ordered for them.

The following communications were read :—

I. "A Contribution to the Knowledge of Hæmoglobin." By E. Ray Lankester, M.A. Oxon., Fellow of Exeter College, and Radcliffe Travelling Fellow of the University. Communicated by Prof. Huxley. Received July 29, 1872.

The fact that exceedingly small quantities of Hæmoglobin can be detected with great facility by means of the microspectroscope, has rendered it possible to trace the distribution of this important body among organisms of various classes, and by comparing its absence from certain animals or

tissues and its presence in others, with the accompanying conditions and activities belonging to the particular organisms, to arrive at some data bearing upon its physiological significance. Such a comparative method has already yielded results as to the activities of many organs and tissues, and is in all probability destined in the future, when applied to the more minute problems of the functions of structures and tissue-components, to give new impulse to the science of physiology.

Before communicating some newly observed facts with regard to the occurrence of Hæmoglobin in animal organisms, I may briefly state what is the present condition of the subject.

After Hoppe Seyler* and Stokes† had shown that the red colouring-matter of the blood of Vertebrata could be recognized by its peculiar absorption-spectrum, Kuhne‡ discovered that the same colouring-matter, the oxygen-carrying properties of which were known from other researches, was diffused in the voluntary muscular tissue of mammals, and imparted to them their red tint. Rollett§ then obtained from the red vascular fluid of the earthworm crystals which were identical with those of Hæmoglobin, and Nawrocki‖ at the same time as myself¶ confirmed the supposition that Hæmoglobin is the cause of the red coloration of the blood of *Lumbricus*, by careful spectroscopic observation of the fluid and the derivatives yielded by it (Hæmatin). I also established by spectroscopic analysis** the existence of Hæmoglobin in the blood of the mollusk *Planorbis*, in that of the larva of the insect *Cheironomus*, in that of the Crustaceans *Cheirocephalus* and *Daphnia*, and in the vascular fluids of the marine Annelids *Eunice*, *Nereis*, *Terebella*, and others. I found also that in the Annelids of the family "Chlorémiens" of Audouin and Edwards, as well as in some species of *Sabella*, the Hæmoglobin was replaced by a body having similar properties, giving a dark red colour to the vascular fluid when seen in sufficient thickness, and a bright green in thinner layers. This body gave a very sharply marked and characteristic pair of absorption-bands in the oxidized condition, which were changed to a single one in the reduced condition, as in the case of Hæmoglobin, the bands, however, having a relative intensity and a position altogether differing from those of Hæmoglobin. By the action of cyanide of potas-

* Hoppe Seyler, "Ueber die chemischen u. optischen Eigenschaften des Blutfarbstoffs," Archiv f. pathol. Anat. u. Physiol. 1862, Bd. xxiii.

† Stokes, "On the Reduction and Oxidation of the Colouring-matter of the Blood," Proc. Royal Society, 1864.

‡ Kuhne, "Ueber den Farbstoff der Muskeln," Archiv f. Pathol. Anat. u. Physiol. Bd. xxxiii.

§ Rollett, "Zur Kenntniss der Verbreitung des Hämatins," Sitzungsber. d. k. Ak. d. Wiss. z. Wien, Bd. xliv.

‖ Nawrocki, Centralblatt für die medic. Wissenschaften, 1867, p. 196.

¶ Lankester, "Observations with the Spectroscope," Journal of Anatomy and Physiology, 1867, p. 114.

** "Spectroscopic examination of certain Animal Substances," *ibid.* 1869, p. 119.

sium, followed by that of a reducing agent (sulphide of ammonium), this body, to which the name Chlorocruorin was given, furnished two absorption-bands identical with those exhibited by Hæmoglobin when similarly treated. Last year I found that the red colour of the pharyngeal muscles of the Gasteropods *Lymnæus* and *Paludina** was due to the presence of Hæmoglobin diffused in the muscular tissue; and at the Meeting of the British Association at Edinburgh I demonstrated its occurrence in the pharyngeal muscular mass of *Littorina*, where it is in sufficient quantity to give a very intense blood-red colour. The interest of this fact consists in this, that in no other part, not even in the blood of these mollusks, does Hæmoglobin occur; hence the doubts which Brozeit† had attempted to throw upon Kuhne's conclusions with regard to the red colour of mammalian voluntary muscular tissue were rendered of less significance than before. It was also mentioned that whilst Hæmoglobin is absent from the unstriped muscular tissue of mammalia generally, it occurs in that tissue in the rectum of man, and probably of other mammals.

Some observations made during the past winter at Naples will tend to enlarge the basis of facts sketched above, upon which I have ventured to make some generalizations with regard to the mode of occurrence of Hæmoglobin in the animal economy.

1. *Occurrence of Hæmoglobin in corpuscles in the perivisceral fluid of the Annelids* Glycera *and* Capitella, *and of the Gephyrean* Phoronis.—Many of the marine Chætopodous Annelids are devoid of that closed vascular system which in others contains a fluid impregnated with Hæmoglobin or Chlorocruorin. *Glycera* is one of these anangian forms; but, as an exception to the general rule, has peculiar corpuscles in its perivisceral fluid which are of a red colour, as was observed by De Quatrefages and confirmed by Claparède. These corpuscles I find, when submitted to the microspectroscope, give an absorption-spectrum identical with that of Hæmoglobin, as proved by the superposition of the spectra. The Hæmoglobin of these corpuscles was readily obtained in both the oxidized and the reduced conditions. The corpuscles (Pl. I. figs. 1, 2, & 3) which contain the Hæmoglobin are round, somewhat flattened, cheese-shaped bodies $\frac{1}{1850}$ of an inch in diameter, possessing a very delicate wall, which often becomes irregularly puckered by increased density of the fluid in which the corpuscles float, and a scarcely visible nucleus about $\frac{1}{5000}$ of an inch in diameter eccentrically placed, which is brought into sharp definition by the action of weak acids, and exhibits granulation of its contents. These corpuscles exhibit a tendency to run into rouleaux, and form aggregations similar to those known in the case of mammalian and other vertebrate red corpuscles. They are by no means so numerous in the perivisceral fluid as are the red corpuscles in vertebrate blood, and are accompanied

* "Verbreitung des Hæmoglobins," Archiv f. gesam. Physiol. 1871.

† "Bestimmung der Blutmenge im Körper," Archiv f. ges. Physiol. Bonn, 1870, p. 353.

by amœboid corpuscles, which are colourless, and by the genital products. When a *Glycera* is irritated so as to cause it frequently to extrude its large pharyngeal tube and jaws, a red line is noticed running along the whole of the ventral surface. This appears to be caused by the pressure of the fluid containing the red corpuscles into the cavity of the outer sheath of the nerve-chord, and may have some functional importance. The corpuscles enter this sheath at its anterior termination*.

2. *Occurrence of Hæmoglobin in the vascular fluid of Turbellarians.*—Quatrefages observed that the fluid in the vessels of the Nemertean worm *Polia sanguirubra* was coloured red. In a species examined at Naples, I have found that this colour is due to Hæmoglobin diffused in the liquid. In by far the majority of cases the vascular fluid of the Turbellaria is colourless. My friend Mr. H. N. Moseley last year observed Hæmoglobin with the spectroscope in a small Planarian at Suez.

3. *Occurrence of Hæmoglobin in corpuscles in the blood of a Lamellibranchiate Mollusk.—Solen legumen*, which is known to the Neapolitan fishermen as "Canolicca femina," has a reddish tint; and this was found to be due to the red colour of the blood, which could be seen very beaufully, like a natural injection, in the blood-sinuses and vessels of the mollusk. When one of the shell-valves was partially removed so as to obtain a clearer view of the underlying parts, the red-coloured fluid could be seen passing from one of the large sinuses to another, as the animal expanded and retracted its long worm-like foot. I would particularly draw attention to the fact that though, when thus irritated, an increased amount of liquid appeared to be exuded from the mollusk, yet this liquid was entirely colourless and devoid of corpuscles—a fact which must qualify existing notions as to the escape of the organized blood-fluid of Mollusca, based upon the well-ascertained existence of apertures communicating with the exterior in their vascular system. If the liquor sanguinis escapes, it is clear that at any rate the corpuscles, in which, as will be mentioned, the red colouring-matter resides, do not. A very slight injury to the tissue of the mantle is sufficient to cause an escape of the red-coloured fluid; and this when placed under the microscope is found to consist of a plasma in which float abundant oval, sharply contoured cells of a red colour (figs. 4 & 5). The red colour was definitely proved to be due to Hæmoglobin by examination with the microspectroscope, giving the two bands identical with those of O, Hb from human blood, and furnishing

* To the case here recorded, of Hæmoglobin occurring in corpuscles among Vermes, I can now add that of the annelid *Capitella*, the corpuscles of which I found similar to those of *Glycera*, and further, the remarkable Gephyrean *Phoronis hippocrepia* (fig. 6). In the annelids *Cirrhatulus* and *Ophelia*, corpuscles occur in the closed vascular system, which contains a liquid in which Hæmoglobin is diffused. Such a vascular fluid is common among the Chætopoda; but these are the only cases known in which it contains corpuscles. On examining these corpuscles, which are very small in number, I find them to be not special Hæmoglobin-bearing corpuscles, but small amœboid particles which are impregnated with Hb, just as the surrounding fluid is.

also the single band of reduced Hb when treated with reducing agents. The corpuscles measure about $\frac{1}{2200}$ of an inch in length and $\frac{1}{3750}$ in breadth. They are by far the most abundant, but not the only corpuscles in the liquid. Colourless amœboid corpuscles are also present. Acetic acid brings out a clearly emarginated nucleus in the red corpuscles. Acetate of rosaniline, both with these corpuscles and the red corpuscles of *Glycera* and of *Phoronis*, stains the nucleus intensely, and gives one or two eccentrically placed maculæ, as was observed by Dr. Roberts in human and vertebrate blood generally. I have not obtained these maculæ in corpuscles devoid of Hæmoglobin; and since, in the cases of *Glycera*, of *Phoronis*, and *Solen legumen*, where this body is present, as in the vertebrate red corpuscles, the Robertsian macula is obtained, there is some ground for believing that the substance which is thus rendered evident by coloration with magenta is connected with the Hæmoglobin, being either a part of its decomposition-product, due to the action of the rosaniline, or a necessary concomitant of it in the blood-corpuscle. Since the other species of *Solen* accompanying *Solen legumen* in the Gulf of Naples have colourless blood, I was anxious to see whether the corpuscles which bear the Hæmoglobin in that species are represented in any way in the others. I therefore examined the blood of *Solen ensis*. I found but few corpuscles present; and these were all perfectly colourless, and exhibited very active amœboid movements, throwing out processes in various directions with great rapidity, and running together into adherent masses on the glass slip; whilst under the microscope magenta brought a large nucleus in them, with brilliant staining, but gave no trace of an eccentric macula, such as that which characterizes Hæmoglobin-bearing corpuscles under similar treatment.

4. *Absence of Hæmoglobin from the blood of the fish* Leptocephalus, *with presence of corpuscles corresponding to the red corpuscles.*—The beautiful little fish *Leptocephalus* is, with the exception of the black-pigmented eyes, perfectly colourless and glass-like. I am not aware of traces of red colour in its blood having been carefully sought for; but there certainly are none. The blood-vessels possess no tint whatever, and the gills, moreover, are perfectly free from colour. Notwithstanding this absence of Hæmoglobin, the blood of *Leptocephalus* presents, as observed by Köl-liker, both the colourless amœboid corpuscles of vertebrate blood and elliptic nucleated corpuscles, also colourless, exactly comparable to those which bear the Hæmoglobin in other fish. This fact is remarkable when put side by side with the observation that the perivisceral fluid of Annelids generally presents no corpuscles comparable to those which bear Hæmoglobin in *Glycera*, *Capitella*, and *Phoronis*. The ordinary amœboid corpuscles are present in both series; and in the latter the Hæmoglobin-bearing corpuscles appear as a special addition.

In *Amphioxus* I may mention that I have not succeeded, after trials, in obtaining spectroscopic evidence of Hæmoglobin, though Wilhelm

Müller, of Jena, states that this vertebrate has corpuscles of a pale red tint. If *Amphioxus* should prove not to, it is yet certain that *Leptocephalus* does form an exception to Prof. Preyer's recent statement in his valuable monograph, 'Die Blutkrystalle,' that Hæmoglobin is found "bei allen Vertebraten."

The statements in the present notice will be found to extend considerably the area of distribution of Hæmoglobin, as given in Prof. Preyer's work, which is the latest (1871) on the subject.

5. *Presence of Hæmoglobin in the tissue of the chain of nerve-ganglia of* Aphrodite aculeata.—The chain of nerve-ganglia of the Annelid *Aphrodite aculeata* possesses a bright crimson tint. This colour is particularly marked in the ganglia themselves, and is most intense in the supraœsophageal ganglion, which has as intense a colour as a drop of fresh human blood. When examined with the microscope, the colour is found to impregnate the nerve-tissue itself, and not to be held in any liquid bathing the tissue.

The vessels of *A. aculeata*, which are not represented in closely allied species (which are anangian according to the researches of Claparède), contain a pale lemon-coloured fluid, which gives no bands with the spectroscope, and is certainly free from Hæmoglobin.

The perivisceral fluid is colourless, and also the muscular tissue throughout the animal, with the single exception of the great muscular pharynx. This has a pale pink tint; and it and the nerve-chain, when examined with the microspectroscope, gave abundant evidence of the presence of Hæmoglobin. The quantity in the pharyngeal muscular tissue is very small indeed; but, on the contrary, excessive in the nerve-ganglia, corresponding with their brilliant crimson colour.

I may mention here that the orange or yellow colour of the nerve-ganglia of many Mollusca is *not* due to Hæmoglobin.

6. *Presence of Hæmoglobin in the muscles of the dorsal fin of* Hippocampus.—The abundance of the little fish *Hippocampus* in the Gulf of Naples has enabled me to confirm an observation made three years ago on specimens which died in the aquarium in Regent's Park. Whilst the other locomotive muscles of this and other fish are quite free from colour, the muscles attached to the base of the dorsal fin are seen to have a pale red colour; and on examination with the spectroscope this colour is found to be due to Hæmoglobin. Microscopic examination proves the colouring-matter to be diffused in the muscular tissue, and not to be due to a special vascularity of the part in question. Probably other specially active muscles of other fishes may be found to be in the same case as those of the dorsal fin of *Hippocampus*; but I have not made any extended observations on this point.

The deep red coloration of the heart in Vertebrata generally is readily proved by the spectroscope to be due to the presence of Hæmoglobin; but owing to the great vascularity of the tissue in some cases, or to its

cavernous structure in others, and its consequent close association with the Hæmoglobin of the blood, this does not seem remarkable. I have not attempted thoroughly to remove the blood from the heart by injection of salt-solution, as was done by Kuhne with the voluntary muscular tissue of Mammals.

The facts ascertained as to the distribution of Hæmoglobin may now be summarized as follows:—

1. In special corpuscles.
   a. In the blood of all vertebrates, excepting *Leptocephalus* and *Amphioxus* (?).
   b. In the perivisceral fluid of some species of the Vermian genera *Glycera*, *Capitella*, and *Phoronis*.
   c. In the blood of the Lamellibranchiate Mollusk *Solen legumen*.
2. Diffused in a vascular or ambient liquid.
   a. In the peculiar vascular system of the Chætopodous Annelids very generally, but with apparently arbitrary exceptions.
   b. In the vascular system (which represents a reduced perivisceral cavity) of certain leeches, but not of all (*Nephelis*, *Hirudo*).
   c. In the vascular system of certain Turbellarians as an exception (*Polia*).
   d. In a special vascular system (distinct from the general blood-system) of a marine parasitic Crustacean (undescribed) observed by Professor Edouard van Beneden.
   e. In the general blood-system of the larva of the Dipterous insect *Cheironomus*.
   f. In the general blood-system of the pulmonate mollusk *Planorbis*.
   g. In the general blood-system of the Crustaceans *Daphnia* and *Cheirocephalus*.
3. Diffused in the substance of muscular tissue.
   a. In the voluntary muscles generally of Mammalia, and probably of birds, and in some muscles of reptiles.
   b. In the muscles of the dorsal fin of the fish *Hippocampus*, being generally absent from the voluntary muscular tissue of fish.
   c. In the muscular tissue of the heart of Vertebrata generally.
   d. In the unstriped muscular tissue of the rectum of man, being absent from the unstriped muscular tissue of the alimentary canal generally.
   e. In the muscles of the pharynx and odontophor of Gasteropodous Mollusks (observed in *Lymnæus*, *Paludina*, *Littorina*, *Patella*, *Chiton*, *Aplysia*), and of the pharyngeal gizzard of *Aplysia*, being entirely absent from the rest of the muscular and other tissues and the blood of these mollusks. See as to *Planorbis* above (2 *f*).
   f. In the muscular tissue of the great pharyngeal tube of *Aphro-*

dite aculeata, being absent from the muscular tissue and from the blood in this animal, and absent from the muscular tissue generally in all other Annelids as far as yet examined.

4. Diffused in the substance of nervous tissue.
   a. In the chain of nerve-ganglia of *Aphrodite aculeata*.

The significance of these observations depends to a large extent on the negative results given by very numerous observations not recorded here. I have taken every opportunity, during some years past, of examining coloured animal matters with the spectroscope, and especially where there could be a suspicion of the presence of Hæmoglobin *. Thus, where the absence of Hæmoglobin is generally stated above, it must be understood that examination has been made for it in such cases as have been accessible. I have found that many cases of red coloration of a tissue or liquid, which might be supposed to be due to Hæmoglobin, are certainly not so, such red-coloured matter failing to give the characteristic bands of that body, and, as a rule, giving no detached characteristic bands. Such are the red pigments occurring in the blood-corpuscles of *Sipunculus*, in the tissues of many Annelids, in Echinodermata, in compound Tunicata, surrounding the intestine of *Salpa*, in the foot and mantle of many Mollusca, also in their nerve-ganglia and other parts, in the chromatophores of Cephalopoda, in certain Infusoria. On the other hand, among coloured bodies not suggesting Hæmoglobin, I have found an equally large number devoid of characteristic spectra, but some few which exhibit the remarkable phenomenon of detached definite bands of absorption, which enables them to be certainly characterized and recorded. Such are :—a chlorophyll-like body occurring in *Spongilla*, in *Hydra viridis*, and in *Mesostomum viride*; Chlorocruorin, which takes the place of Hæmoglobin in the vascular fluid of the Chlorémiens and some species of *Sabella*; Stentorin, giving the intense blue colour to the Infusorian *Stentor cæruleus*, and possessing a very marked and peculiar pair of absorption-bands. With one single exception, it appears, from the examination of a great number of cases, both among Vertebrates and Invertebrates, that coloured bodies which may be supposed to be purely pigmentary in their function do not give detached absorption-bands. The exception is the red colouring-matter named Turacin by Professor Church, discovered by him in the feathers of birds of the family Musophagidæ, which has other properties quite unusual in pigmentary bodies. In an examination of a large number of birds' feathers, red, yellow, blue, and green, I failed to obtain detached absorption-bands, as

* I may state that I have not hitherto made any observations on the colouring-matters of the biliary secretion in Invertebrata and the lower Vertebrates, excepting in their fresh condition. The use of the spectroscope, combined with chemical reagents, would no doubt lead to interesting results in that field, since a variety of substances giving characteristic absorption-spectra have been obtained from the manipulation of mammalian bile-pigment.

also in the scales of fish and in the skin and hair of mammals, and in the pigments of many Crustaceans, Annelids, Insects, Tunicates, and Sponges *.

From a consideration of the facts stated above with regard to the mode of occurrence and distribution of Hæmoglobin in animal organisms, the following general statements may be made, which are in accordance with the now thorough establishment, by chemical investigation, of its peculiar oxygen-carrying property.

Hæmoglobin is irregularly distributed throughout the animal kingdom, being absent entirely only in the lowest groups†. It may be present in all the representatives of a large group, with but one or two exceptions, or it may be present in one only out of the numerous members of such a group; or, again, it may be present in one and absent in another species of the same genus. It may occur in corpuscles in the blood, or diffused in the liquor sanguinis, or in the muscular tissue, or in the nerve-tissue. The same apparent capriciousness characterizes its occurrence in tissues as in specific forms. It may be present in one small group of muscles and absent from all the rest of the tissues of the body, or it may occur in one part only of a tissue, histologically identical throughout its distribution in the organism. The apparently arbitrary character of this distribution is to be explained (though only partially) by a reference to the chemical activity of Hæmoglobin. Wherever increased facilities for oxidation are requisite, Hæmoglobin may make its appearance in response; where such facilities can be dispensed with, or are otherwise supplied, Hæmoglobin may cease to be developed.

The Vertebrata and the Annelida possess a blood containing Hæmoglobin in correlation with their greater activity as contrasted with the Mollusca, which do not possess such blood. The actively burrowing *Solen legumen* alone amongst Lamellibranchiate Mollusks, and amongst Gasteropods only *Planorbis*, respiring the air of stagnant marshes, possess blood containing Hæmoglobin. In the former the activity, in the latter the deficiency of respirable gases are correlated with the exceptional development of Hæmoglobin. But we cannot as yet offer an explanation of the absence of Hæmoglobin from the closely allied species of *Solen*, and from the *Lymnæi* which accompany *Planorbis*. The Crustaceans *Cheirocephalus* and *Daphnia*, and the larva of *Cheironomus*, possessing, as exceptions in their classes, Hæmoglobin in their blood, inhabit stations where the amount of accessible oxygen must be small (that is to say, stagnant ponds), the last living in putrescent mud; whilst the possession

* See Journal of Anatomy and Physiology, 1869–70, p. 119.

† [*Note.* Dec. 24th, 1872.]—It is perhaps of some significance that Hæmoglobin has only been found in that great group of the animal kingdom which in the course of its development gives rise to a middle layer of blastodermic cells or mesoderm, and in examples from nearly every great branch of this stem.

of abundant Hæmoglobin in its vascular fluid may be supposed to be one of the chief properties which enables the oligochæt Annelid *Tubifex* to hold its ground in the foul, and therefore much deoxygenated, water of the Thames at London.

The known chemical properties of Hæmoglobin furnish a more complete explanation of its peculiar distribution in tissues. That it should occur in a circulating fluid, which is the medium of respiration, is obviously related to those properties. Its occurrence in the voluntary muscles of the most active of Vertebrata, and in the most active muscles of some others (as in the case of the dorsal-fin muscles of *Hippocampus*), is equally so; so also its occurrence in the most powerfully acting part of the intestinal muscles, those of the rectum, and in the only rapidly and constantly acting muscles of the Gasteropods, namely those used in biting and rasping.

To connect its occurrence in the nervous chain of *Aphrodite aculeata* with its properties is more difficult, since we have no knowledge that this Annelid is remarkable for nervous energy. The large bulk of the animal in proportion to the size of the nervous system, and the deficient respiration, indicated by the very slightly developed vascular system and the total absence of Hæmoglobin from the fluids of the worm, may be a reason for the endowment of the nervous centre which has to control such a large and complicated organism with a special facility for appropriating what little oxygen may come in its way.

The complete absence of Hæmoglobin from *Leptocephalus* is an example of the submission of an auxiliary, but not an essential, structural attribute to an all-powerful necessity—that of transparency. The absence of Hæmoglobin from the transparent Annelid *Alciope* may be similarly correlated.

From what has been stated above as to the Hæmoglobin-bearing corpuscles of *Glycera*, *Solen*, and the Vertebrata, it appears that when Hæmoglobin is present in the blood in *corpuscles*, these corpuscles are of a peculiar character, and are specially related to the presence of the Hæmoglobin. When that is absent, other things remaining the same (as with the blood of *Solen ensis* and the perivisceral fluid of most Annelids), the peculiar corpuscles are absent. Such things as colourless corpuscles, representative of the Hæmoglobin-bearing corpuscles, do, however, appear to exist in the case of the fish *Leptocephalus*. In connexion with the relation of the colourless corpuscles of vertebrate blood to the red corpuscles, and of the corpuscles of the vascular fluids of Invertebrata to one another and to those of Vertebrates, these facts seem to be important: the colourless corpuscles in one case are only comparable to the colourless in another; the red corpuscles are something apart, which may or may not be superadded*.

* [*Note.* Dec. 24th, 1872.]—The two kinds of corpuscles may be definitely distinguished from one another as *leucocytes* and *pneumocytes*.

The corpuscles of the perivisceral fluid of the Gephyrean *Sipunculus nudus*, which is abundant in the Gulf of Naples, present some facts which are interesting in relation to the occurrence of Hæmoglobin; and I may therefore draw attention to them before concluding this paper. The fluid which is contained in the perivisceral cavity of this worm is, as is well known, of a pale madder-red colour. It contains a remarkable abundance and variety of corpuscles, the most numerous of which are thick circular disks, varying in diameter from $\frac{1}{3500}$ to $\frac{1}{2000}$ of an inch; and in these, and these only, the pink colour resides (fig. 7). These pink corpuscles consist of a clear homogeneous substance, of high refringent power, in which are scattered three or four bright granules and a small nucleus, which is rendered obvious by the action of acetic acid. Rosaniline stains this nucleus, but does not usually give any other maculæ, such as are to be observed when it is added to Hæmoglobin-containing corpuscles*. Dr. Alexander Brandt, in a recent memoir, very rightly insists on the similarity between these pink corpuscles of *Sipunculus* and the red corpuscles of the blood of Vertebrata: they are something quite distinct from the amœboid corpuscles found in the fluid corresponding to blood in nearly all Invertebrata, and are to be compared to the red corpuscles of *Glycera*, *Solen*, and Vertebrates. The amœboid corpuscles are otherwise represented in the perivisceral fluid of *Sipunculus* by numerous active amœboid cells. Dr. Brandt, naturally enough, regarded the pink colour of these corpuscles as favouring their assimilation to vertebrate red corpuscles. The colour *en masse* is, however, obviously different from that of dilute Hæmoglobin; and I was not therefore surprised to find that it did not give the absorption-spectrum of that body. This pink colouring-matter is soluble in water. When a little fresh water is added to some of the perivisceral fluid in a tube, it takes up all the colour, whilst the corpuscles sink in a colourless condition to the bottom. No detached bands of absorption of any kind were given by the colouring-matter thus obtained; a slight acidulation with acetic acid was sufficient to destroy the colour. Ammonia had the same action, also ether and alcohol.

Though this pink substance is thus devoid of the spectral properties which characterize Hæmoglobin and Chlorocruorin, it does not seem improbable that it is a body analogous to them in other properties, since the corpuscles in which it resides can only be compared to the respiratory or oxygen-carrying corpuscles occurring in the blood of Vertebrates and the four Invertebrates noticed in this paper. Moreover this pink colouring-matter occurs in other parts of the organism of *Sipunculus*, namely, diffused in the substance of a remarkable tissue which runs along the wall of the intestine, forming a red streak, which has sometimes been taken for a blood-vessel, and also in the peculiar cellular tissue which surrounds the true nerve-tissue of the nerve-chord.

* On one occasion out of many I obtained an appearance of the kind; and hence further observation on this point is necessary.

GLYCERA

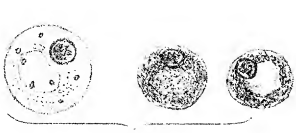

Fig. I.

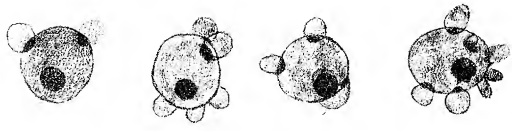

Fig. II.

GLYCERA.

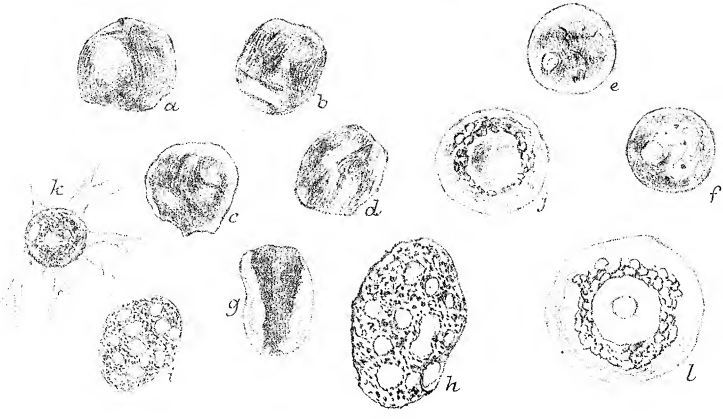

Fig. III.

SOLEN

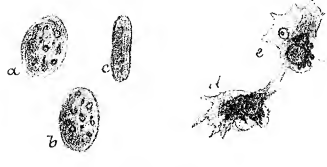

Fig. IV.

SOLEN

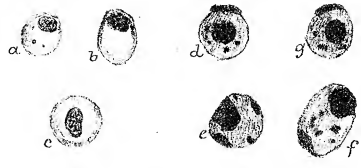

Fig. V.

PHORONIS

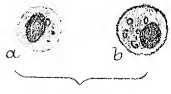

Fig. VI.

SIPUNCULUS.

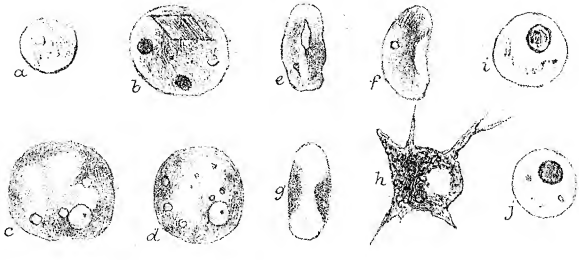

Fig. VII.

The occurrence of colourless corpuscles in *Leptocephalus* identical in form and character with the Hæmoglobin-bearing corpuscles of the blood of other fish, and the apparently capricious distribution of Hæmoglobin among Invertebrata, together with the existence of the green oxygen-carrier Chlorocruorin and the pink colouring-matter of the corpuscles of *Sipunculus nudus*, suggest the hypothesis of the existence of various bodies not necessarily red, possibly colourless, which act the same physiological part in relation to oxygen as does Hæmoglobin.

DESCRIPTION OF PLATE I.

Fig. 1. *Glycera.* Red corpuscles acted on by acetic acid.
Fig. 2. *Glycera.* Red corpuscles acted on by magenta.
Fig. 3. *Glycera.* *a* to *f*, normal red corpuscles; *g*, seen laterally; *h*, *i*, testicular cell-masses; *k*, leucocyte; *j*, *l*, ova.
Fig. 4. *Solen legumen.* *a*, *b*, *c*, normal red corpuscles; *d*, *e*, leucocytes of *Solen ensis* identical with leucocytes of *S. legumen*, with nucleus stained by magenta.
Fig. 5. *Solen legumen.* *a*, *b*, *c*, red corpuscles acted on by dilute acetic acid; *d*, *e*, *f*, *g* ditto acted on by magenta.
Fig. 6. *Phoronis hippocrepia.* Red corpuscles acted on by dilute acetic acid.
Fig. 7. *Sipunculus nudus.* *a* to *g*, normal pink-coloured corpuscles of the perivisceral fluid; *b* contains a crystal; *h*, leucocyte from the same fluid; *i*, *j*, pink corpuscles (pneumocytes) acted on by dilute acetic acid.

II. "On the Structural Composition of Urinary Calculi." By H. Vandyke Carter, M.D. Lond. Communicated by L. S. Beale, M.D., F.R.S. Received October 11, 1872.

(Abstract.)

Having occasion during his late residence in Western India to remove numerous urinary calculi from persons belonging to the indigenous population, the author was enabled to pursue an inquiry into the character of these concretions which he had begun in the year 1859 by the chemical analysis of a large number of such calculi; it remained then to make use of the microscope as a means of investigation; and since no record of a similar systematic inquiry to that now undertaken has been published, so far as known to the author, it was thought desirable that this *hiatus* in medical literature should, however imperfectly, be forthwith filled up.

The plan adopted was to submit minute fragments taken from the real or apparent nuclei, and from succeeding layers and crust, of the calculi examined to the scrutiny of average optical powers, the highest available magnifying about 300 diameters. Distilled water was the ordinary medium employed; and in all cases chemical tests were conjointly used for the purposes of detection or confirmation. After sufficient practice, it became apparent that the microscopic analysis of calculi, thus carried

GLYCERA

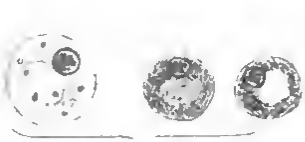

Fig I

Fig II

GLYCERA

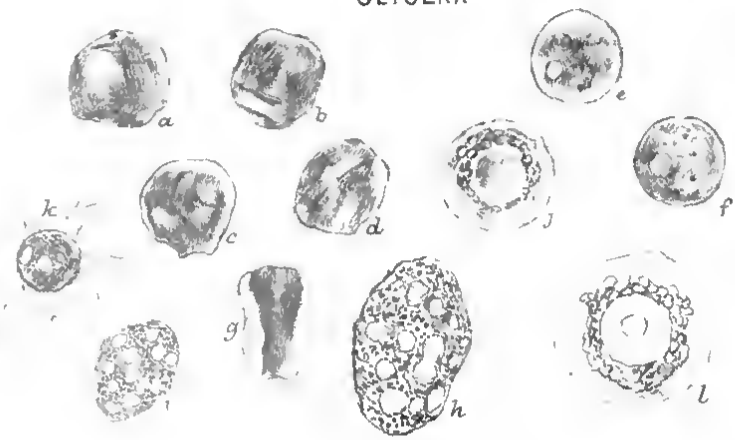

Fig III

SOLEN

Fig IV

SOLEN

Fig V.

PHORONIS

Fig VI

SIPUNCULUS

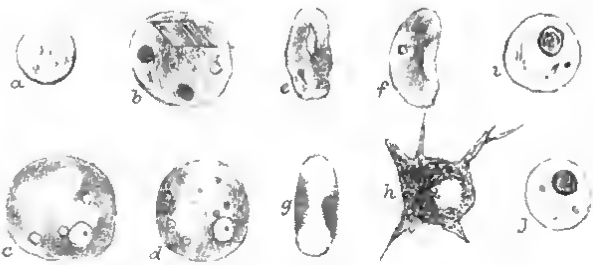

Fig VII